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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

CENTER FOR ENERGY CONSERVATION

Swimming Pool Circulation System Energy Efficiency Optimization Study

FINAL REPORT

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EXECUTIVE SUMMARY

INTRODUCTION

This report presents the results of a study of ways to optimize the operating efficiency *of* residential swimming pool circulation systems. Reduction *of* pump operating hours, cost effective retrofitting of existing pools and design of cost effective energy efficient new pools were explored. At the outset of the project, it was believed that a 50 per cent reduction in kWh consumption for swimming pool pumps was achievable, along with a nearly 100 per cent reduction in kWd during utility peaking hours. It now appears that even greater kWh savings are possible, and that the expectation for kWd reduction is realistic given full customer cooperation.

During the course of the project, operating hours for South Florida participating pools were reduced from an average of 7.74 hours in summer and 6.65 hours in winter to an average *of* 3.35 hours in summer and 2.48 hours in winter. These reductions represent an annual average savings of 1827 kWh, based on a measured average kW of 1.17 for the circulating pumps, along with a 180 day summer season and a 185 day winter season. In North Florida, an average annual savings of 1699 kWh was achieved for the St. Augustine area and an average annual savings of 1545 kWh was achieved for the Lake City area.

The results of a random survey of non-participants yielded an average summer pump running time of 8.7 hours, indicating an even greater kWh savings opportunity if all swimming pools in the Florida Power & Light Co. service area are considered.

The major reductions in operating hours along with biweekly monitoring of time clock settings greatly reduced the possibility that any of the project pools would be operating during utility peaking hours. In addition, the final time clock settings upon project completion decreased the likelihood that pumps would run during peak hours as a result of time clock slippage.

Throughout the project, differing opinions were encountered on the correct *way* to maintain a swimming pool. The implication of the abundance of opinions is probably that there is no single "correct" way to operate a pool. However, there is a demonstrated need for the development and implementation of programs which will train pool owners and pool professionals in the energy efficient construction and operation of swimming pools.

OPERATING HOURS STUDY

A study *of* the effect of reducing operating hours was conducted over the winters of 1982-83 and 1983-84 and over the summers of 1983 and 1984. A total of 66 pools in South Florida and 53 pools in North Florida were included in the study. The objectives of this phase of the study were to:

1. Establish a data base of typical pools in the two regions, and,
2. Determine what variables most significantly affect the amount of pump running time needed to achieve clean and sanitary pool water conditions.

The following conclusions were reached:

1. A theoretical analysis of forces acting on particles in swimming pools indicates that most filterable particles in a swimming pool can be expected to sink to the bottom within a few hours or less if no source of agitation is present. On the other hand, molecular-sized particles can be expected to be essentially uniformly distributed throughout the pool volume due to random thermal motion. In other words, dirt sinks to the bottom and chemicals stay in solution whether or not the circulating pump is running.

2. In most pools, increasing the pump running time above two hours results in imperceptable improvement in water quality. Since over 90 per cent of project participants were running their pool pumps for 4 hours or less by the end of the program despite the wide range of physical characteristics of the pools, it has been concluded that physical characteristics of pools do not affect the ability of the circulating pump to maintain satisfactory water conditions. Pools requiring longer pump running times usually are characterized by idiosyncratic conditions such as heaters, unusual contaminant load, or improperly functioning automatic cleaners or automatic chlorinators.

3. The decoupling of pump operating hours from other physical characteristics of pools is especially significant in view of the fact that the experimental pools were representative of pools belonging to people willing to cooperate rather than an ideal random sample. It is not known to what extent the results of this study might be implemented by the remaining pool owners in Florida, but at least it can be said that the results of this study are applicable to the larger group.

4. In most cases, cutting back on circulation pump operating hours does not increase the need for brushing and vacuuming. That is, the amount of contaminants entering a pool is independent of pump operation, and most contaminants are removed via brushing and vacuuming as opposed to via routine circulation.

5. Running the circulating pump shorter hours does not increase the chemical requirements of a swimming pool. This observation is consistent with conclusion (3) since the amount of chemicals needed depends on a number of factors, none of which depend on how long the pump is run.

6. Pool owners in the study generally preferred to run their pumps on split schedules, such as 1.5 hours in the morning and another 1.5 hours at night.

There is no evidence that split schedules result in less maintenance, but apparently pool owners feel better about running the pump once every 10.5 hours rather than once every 21 hours. Split schedules of 1.5 hours can provide attractive utility load diversification.

7. It is not necessary to circulate the entire volume of water in a residential pool once a day. Circulation systems are usually designed to provide one complete turnover in 6-10 hours. It appears that after the debris has been skimmed from the pool surface (normally 30 minutes or less); the pump circulates clean water unless the dirt on the bottom is being agitated.

8. Algae can form on pool walls even if the circulating pump is run 24 hours per day. In other words, running the circulating pump is not a substitute for proper physical and chemical maintenance of a pool.

9. No evidence was obtained to indicate that running a pump during daylight hours results in better pool condition pump than running a pump at night.

10. It is not essential to run the circulation pump when swimmers are in the pool, except when the pool is subject to large bather loads over a prolonged time period such that contaminant build-up results in unacceptable water quality.

11. A good compromise recommendation for circulation pump operating hours is 9:00 a.m. to 12:00 noon; this schedule results in substantial reduction of kWh and kWd, but still meets most owner needs.

12. When compared with a random sample of non-participating pools, project pools showed no significant differences in either maintenance requirements or in chemical usage. However, the project pools reported significantly fewer incidences of algae. This result is in a direction opposite to what might have been expected, and is an important observation in support of the contention that running the pool pump is not a substitute for proper physical and chemical maintenance.

RETROFITTING FOR ENERGY EFFICIENCY

After the first winter of setting back time clocks, it was observed that the ratio of pool volume to minimum achievable monthly kWh for pump operation (VOL/MKWH) ranged from 53 to 436 in South Florida and from 79 to 794 in North Florida. Using these figures as measures of relative performance efficiency, it can be seen that pools in the south differed in operating efficiency by a factor of 8:1, while pools in the north differed in operating efficiency by a factor of 10:1.

In an attempt to determine whether cost-effective improvements in energy efficiency could be made, 20 pools in the south and 3 pools in the north were retrofitted with new equipment.

The retrofits involved replacement of pumps, filters, time clocks, and, in several cases, modifications of the plumbing systems. Replacements were made on an emergency basis as some of the old equipment failed, and on a planned basis as the problems with the least efficient pools were identified. Most retrofit work was confined to the south as a matter of cost and expedience.

As a result of the installation of smaller and more efficient new pumps, the winter VOL/MKWH for a group of 12 pools in the south was increased from an average of 206 to an average of 331, with a corresponding 463 kWh per year average energy savings over and above the savings achieved with time clock set backs. In addition, a reduction of an average of 0.52 kW was achieved for the operating power of these systems.

The effect of this 0.52 kW on the utility diversified peak load has not been established, since it is not known what fraction of the total number of pool owners will insist on running their pumps during peak times, nor is it known the degree of time clock slippage which might be expected from pools which might participate in a reduced running time program.

On the basis of the retrofits completed, the following observations can be made:

1. The achievable savings in kWh and kWd is limited by the sizes of pumps currently available in the marketplace. It is difficult to purchase pumps smaller than 0.75 HP, even though pool hydraulics are best suited for smaller sizes.

2. It is estimated that a large-scale pump replacement program could result in a savings of 423 kWh per year per installation on the average. This figure could be larger if smaller HP pumps were to become more readily available. Since smaller HP pumps are less costly than larger pumps, there is no economic barrier to replacing larger pumps with smaller ones. The first cost is less and the operating costs are less. The only barrier to overcome is the disbelief that smaller pumps can do the job effectively.

3. If a pump and filter are replaced, the total cost is essentially the same if a small pump and large filter are substituted for a large pump and small filter. However, the operating cost is less and less maintenance is required on the filter.

4. When replacing a pump, use a 0.75 HP or smaller size if the pipe size is 1.5-inch.

5. When replacing a pump or filter, eliminate as many sharp 90 degree elbows as possible by replacing them with sweep 90degree elbows, 45-degree elbows or flexible pipe.

6. When replacing a filter, replace it with a filter rated at a minimum of 50 per cent more than the design flow rate.

7. Observe carefully water circulation patterns in a pool. Improperly adjusted eyeballs can cause circulation problems.

8. When replacing a time clock for an unscreened pool or one surrounded by heavy vegetation, consider using a clock which will allow a minimum running interval of 15 minutes or less. The clock can be set to provide skimming action every few hours.

9. It appears that incentive programs to encourage Replacement of circulating pumps with smaller HP replacements might be a promising way to further reduce kWh and kWd.

ENERGY EFFICIENT CONSTRUCTION OF NEW POOLS

Six new pools were constructed during the course of this project. Although six is hardly a statistically significant sample, each case demonstrated that the combination of smaller pump, larger filter and larger piping is a cost-effective means of achieving energy efficiency. General construction guidelines and operational cost estimates are presented in Tables 6.1 and 5.3. The marginal cost of energy efficiency improvements is generally about $50, and seldom exceeds $100 for a typical pool.

FREEZE PROTECTION STUDIES

A common practice among owners of swimming pools in regions which have occasional freezes is to run the circulating pump all night in order to prevent it from freezing. Some pool owners run their pumps every night during the winter to be sure that the pump will run on freezing nights. The following observations are offered, following a pilot study of freeze protection systems installed on 5 pools in Lake City, Florida:

1. It takes only a few minutes of pump operation each hour to prevent the pump from freezing. The installation of either a time clock with short running intervals or a closed loop freeze protection system can provide for such operation of the pump.

2. On the average, each freeze protection installation will remove 1.1 kWd from utility winter peak generation requirements.

3. In addition to kWd reduction, if 8 hours per day of running time can be eliminated from January to March, nearly 800 kWh per pool can be saved per year.

4. The incremental cost of freeze protection devices to achieve the previously mentioned results is about $100, depending on the exact device selected. 'Hence, freeze protection can be cost effective for pool owners and utilities alike.

CHAPTER 1

BACKGROUND OF STUDY

1.1 PROJECT OBJECTIVES

The characterization and retrofitting of swimming pool filter systems to minimize energy consumption was undertaken to establish a reliable estimate of the potential savings in energy which might result from improved circulation system efficiency. The project had several goals:

1. Establish a data base of typical pools in two climatic regions: South Florida, where essentially all pools are operated year-round, and North Florida, where most pools are operated year-round, but some pools are covered during the winter season. In this project, North Florida is considered to be those parts of the state which have a heating season of 100 or more heating degree days. South Florida is the remainder of the state. Swimming season length is discussed in Chapter 4. (see full version)

2. Analyze the low energy consuming pool circulation systems (annual kWh below 1000) as well as the high energy consumers (annual kWh above 3000) to determine whether the high or low consumption can be attributed to equipment efficiency, operating and maintenance practices, both, neither or a combination of the two.

3. Develop a series of recommendations for operating and retrofitting existing pools and for the design of new pools which involve the cost-effective application of modern energy efficient technological developments.

Each of these major goals has been met. The appendices of this report contain summaries of data collected on field visits to pools in two different regions of the state. An analysis of energy efficiency in pool circulation systems has been made and is contained in the body of this report. Recommendations for retrofitting existing-pools and for the design of new pools are contained in the text and repeated in the executive summary of this report.

1.2 REVIEW OF POOL CARE PUBLICATIONS

Publications on energy efficient pool design have been written by equipment manufacturers and by the National Spa & Pool Institute. There are a few publications that deal with energy considerations for pool maintenance.

Most of these publications were written after the energy price shocks of 1979-1980 and they reflect the first serious attempt to define energy efficient pool operation. They do not represent results of any scientific study on the subject but rather a desire to create an awareness of the issue.

NSPI has a publication for pool owners entitled, "Save Energy, Save Money...Energy efficient pool care guide." The publication suggests:

Reduce filter operating times to no less than 4 or 5 hours per day during the summer and 2 to 3 hours per day during the winter period...This will reduce annual electric consumption by 40 to 50 percent...Should water clarity or chemical imbalance indicate inadequate filtration, immediately operate the filter until acceptable water clarity has again been established. If additional filtration is still indicated, increase filter operating time in one half hour increments until the water remains clear and properly balanced chemically.

The publication also suggests:

> Regular maintenance is another key to efficient--and energy-saving--operation of your pump and filter. Leaves and other debris can clog the filter and the strainer baskets in the pump and skimmer, causing the pump to draw on more energy to do its job...When the time comes to replace your pump and motor' or filter, talk with an NSPI member to see if a different size might be more energy efficient.

NSPI has a publication for pool builders entitled, "Energy Efficient Sizing of Swimming Pool Pumps, Motors, and Filters."

This publication notes:

The Institute recommends that the filtration system of a residential pool be run for the minimum time necessary to keep the water in a clear and sanitary condition...The required length of pump operation should be empirically established by slowly reducing it until the water begins to develop a slight cloudiness or haze not attributable to inadequate disinfectant residual, improper pH or chemical imbalance, then increasing it to a slightly longer period.

Without access in 1980 to empirically derived data, the report noted cautiously that "most residential pools can be maintained in a clear and sanitary condition with six to eight hours of filtration each day."

The Florida Power & Light Company Residential Pool Pump Program began in June 1981. Objectives of the program are to reduce the use of residential pool pumps at times of system peak and reduce overall operation of pool pumps when applicable. These objectives have assisted FPL in reaching its conservation goals of reducing the growth of peak demand and kilowatt-hour consumption, and the use of oil. Based on original input from NSPI, the program recommends that pool pumps be set to operate six hours a day in winter and eight hours a day in summer during off peak hours. The Energy Management Planning Department published a study of the program in August, 1983. The study reported that the program had resulted in some conservation of demand (0.33 kWd at the summer peak hour and 0.12 kWd at the winter peak hour, per participant) and energy (582 kWh per participant per year). The major problem with the program was the drop-out rate:

This study conducted one year after the introduction of the program found the majority of participants (61%) had "dropped out" from operating their pool pumps within the program's recommended hours. The "drop out" rate was caused by tripper settings being changed after enrollment (27%), pool clock time being out of alignment with the actual time (13%), or both reasons (21%).

Pool pump timers were set to run from 9 a.m. to 3 p.m. in the winter and an additional *9:00* p.m. to *11:00* p.m. in the summer. A change for whatever reason was fairly likely to bring pool pump operation back to the system peak hour of 5 - 6 p.m. Three recommendations were made; viz., improve customer awareness, implement time-of-use rates, implement load control. At the time, recommending shorter hours of pump operation was not considered.

Guidelines for energy efficient pool design also have had some problems in implementation. Major manufacturers of pool equipment have produced useful guide sheets on sizing circulation system components. These guide sheets contain pump performance curves and recommendations for filter sizing. A few mention the head loss associated with pipe fittings and small diameter piping. Pool designers must, therefore, consult a number of different documents to find the information necessary for calculating system head loss. As a consequence some of the useful information that has been published is frequently not used.

The NSPI booklet entitled "Energy Efficient Sizing of Swimming Pool Pumps, *Motors* and Filters" states that .50 HP pumps can circulate the entire volume of pools up to *20,000* gallons (17'x35') in 8 hours or less. The sizing guide specifies .50 HP or .75 HP on pools of up to *30,000* gallons (20'x40'), even in systems where the total dynamic head is as much as 50 feet--an unnecessarily high resistance to flow.

The literature on pool pump sizing does not generally address a belief that is common to many pool builders: If a .50 horsepower pump is adequate, then a full horsepower is better. The publication "Energy Efficient Sizing of Swimming Pool Pumps, Motors and Filters" gives a helpful example showing that a small pump (.75 HP) connected to 2 inch piping can produce greater flow than a large pump (2 HP) connected to 1 1/2 inch piping. Since the flow rate is of paramount importance in the design of a circulation system, the proper matching of pump to pipe size is worth a great deal of emphasis. Further discussion of efficient hydraulic design is presented in Chapter 6 of this report.

The remainder of this report addresses the applicability of the content of these publications in light of data collected over the past 1.5 years on the operation of approximately 120 Florida swimming pools (Chapter 4). In addition, theoretical considerations of design, maintenance, retrofitting and general water condition are discussed in Chapter 2. Chapter 3 provides an assessment of the validity of time-honored recommendations and claims; Chapter 5 discusses methods of achieving greater energy efficiency in existing pools through retrofitting; Chapter 6 discusses energy efficient design of new pools and Chapter 7 discusses reduction of winter kWd through freeze protection strategies.

Chapter 2 (see full version)

2.8 CONCLUSIONS

Every pool is subjected to its own special collection of contaminants. Hence, any generalizations made can not be expected to apply to all pools. The calculation of sinking times for various particle sizes and densities agrees well with the following observation:

IN MOST POOLS, INCREASING THE PUMP RUNNING TIME ABOVE A FEW HOURS RESULTS IN IMPERCEPTIBLE IMPROVEMENT IN WATER QUALITY.

In exceptional cases, where contaminants have a very low density, it may be necessary to run the pump longer to achieve acceptable particle removal.

Once debris has sunk to the bottom, unless it is somehow moved toward the main drain, skimmer or a vacuum attachment, it will remain on the bottom. There is little reason to run a circulating pump when all filterable material is on the bottom. Flow patterns can be set up to sweep at least some sections of the bottom when the pump is running, but most of the time the pump is circulating clean water.

More work remains to be done on regional and area differences in particles. It appears that in South Florida, most contaminants are relatively large and/or dense. North Florida appears to have more pollen and other seasonal contaminants which are less dense. Many of these particles are less dense than water and can thus be more "effectively removed by skimming action.

It appears that the only reason why the results of this study might not generalize to other areas might be due to variations in contaminants which enter the pool and possibly to variations in water temperatures.

The easiest way to find out is to try running pumps few hours per day and observe the results.

CHAPTER 3
ASSESSMENT OF COMMON BELIEFS ON POOL CARE

There are a number of beliefs about pool care which can now be evaluated on the basis of experimental data. These beliefs seem to be based on a combination of field observations and either deductive or inductive reasoning; nevertheless they contain faulty elements which obscure their basis. Ten of the most common misconceptions are listed here, along with observations and supporting data based on the results of the present study. Further research may contribute to the clarification of particular points.

BELIEF #1. "IT IS NECESSARY TO RUN THE POOL PUMP SIX HOURS A DAY IN WINTER AND EIGHT HOURS A DAY IN SUMMER."

Observation: Most pools can be maintained in sparkling condition with pool pump run times of four hours or less.

Data: More than 100 pools with daily run times of four hours or less were monitored over a 2-year period. A comparison was made of water quality between the experimental pools and a random sample of non-participating pools which were run an average of more than 8 hours per day. There was no significant difference in owner satisfaction with pool water. quality. Running the pump for one turnover period per day (between 6 and 12 hours) appears to be beneficial only while certain water clarity problems involving suspended materials such as dead algae are being treated. One turnover per day is not a requirement for balanced pools in good condition.

BELIEF #2. "CUTTING BACK ON POOL PUMP HOURS INCREASES THE NEED FOR CHEMICALS."

Observation: No evidence ~accumulated to date points to increased chemical demand in pools with short hours of circulation.

Data: Owners of participating pools and a random sample of owners of non-participating pools were asked whether they used more chemicals during summer of 1983 than summer of 1982. No significant difference was found between the responses, even though the participating pools were run an average of nearly 5 hours less per day during summer of 1983. Two pool service companies which have experimented with shorter run times have reported no noticeable change in chemical demand.

BELIEF #3. "CUTTING BACK ON POOL PUMP HOURS INCREASES THE NEED FOR BRUSHING AND VACUUMING."

Observation: In most cases, cutting back on pool pump hours does not increase the need for brushing and vacuuming.

Data: Brushing and vacuuming depends on the amount of debris which enters the pool. Depending upon the effectiveness of the skimmer and depending on the nature of the debris, the first 15 minutes of pump operation will skim off most surface debris. Any further filtering will depend on whether debris on the bottom of the pool has been stirred up enough to be attracted to the main drain. If the bottom debris has not been stirred up, operation of the pump after the first 15 minutes or so will result in the filtering of clean water.

Cases where shortened pump hours affect pool cleanliness involve either automatic cleaners or situations where the pool is surrounded by heavy vegetation. Most automatic cleaners can do their job in 3 hours or less per day. If automatic cleaners are not used on a daily basis, they may take longer to do their job when they are used. However, on days when they are not used, pump hours can be left at the minimum for effective skimming. This minimum run time differs for each pool, but usually does not exceed 2 hours per day.

BELIEF #4. "IT IS NECESSARY TO CIRCULATE ALL THE WATER IN A POOL AT LEAST ONCE A DAY."

Observation: Most pools do not require a complete turnover of water every day for filtration purposes.

Data: Out of 113 pools which remained in the program for two winters and two summers, 105 were run with less than one turnover per day for that period without any noticeable change in pool water quality. Theone turnover per day rule is based on the assumption that materials requiring filtering remain suspended uniformly throughout the pool volume. However, materials requiring filtering normally either sink or float.

BELIEF #5. "CIRCULATING WATER WILL KEEP ALGAE FROM FORMING ON STEPS AND POOL WALLS."

Observation: Algae can form on pool walls and steps, even if the pump is run 24 hours per day.

Data: Observation of more than 100 pools for a 2-year period indicates that running the pump is not a substitute for proper physical and chemical maintenance of a pool. Project pools developed algae when they were neglected; no matter how long the pumps were running--including 24 hours per day.

BELIEF #6. "HAVING THE PUMP TURN ON AND OFF MORE THAN ONCE A DAY WILL USE MORE ELECTRICITY AND CAUSE THE MOTOR TO BURN OUT FASTER."

Observation: Motors are designed to be able to withstand tens of thousands of starts during their lifetimes. The amount of electricity used to start a motor is equivalent to the amount of electricity used during about 2 seconds of normal operation. Hence, if a motor can be shut off for more than 2 seconds, operating cost will be reduced.

Data: At a cost of $.08 per kWh, one rotation of the horizontal "wheel with the black spot" on a residential kWh meter represents a cost of either $.0003 or $.0006, depending on the Kh factor of the meter. When a motor starts, the "wheel" will jump and then settle down to a constant speed of rotation. The amount the "wheel" rotates during the jump is the electricity consumed during the start. Usually the jump will not involve more than 1/10 revolution of the "wheel." This means the pump can be started nearly 200 times for a penny's worth of electricity.

BELIEF #7. "THE POOL PUMP SHOULD BE SET TO RUN DURING DAYLIGHT HOURS."

Observation: Routine pump operation need not occur during day light hours.

Data: There is no evidence to prove the claims that not running the pump during daylight hours will lead to problems with the pool due to lack of chemical circulation, algae growth or loss of chemicals. In an unheated pool the only valid reasons for not running a pump at night are noise and cleaning. If a pool is being cleaned manually, the pump needs to be running. Automatic cleaners work at night without any problems.

BELIEF #8. "THE PUMP SHOULD ALWAYS BE ON WHEN SWIMMERS ARE IN THE POOL."

Observation: Pumping through the filter keeps the water free of debris. Chemicals keep the water sanitary. As long as the cleanliness of the water is acceptable, it is not necessary to run the pump when swimmers are in the pool.

Data: When bottom debris is stirred up, it can be removed from the pool if it works its way to the
Main drain. Swimmers usually stir up the pool and thus help the pump and filter to do their work. However, it is not essential that the pump be run for the benefit of the swimmers.

BELIEF #9. "THE PUMP MUST BE RUNNING TO KEEP THE CHEMICALS MIXED AND WORKING."

Observation: Evidence based on field observations and theoretical analysis suggests that chemical mixing and action does not depend on pump operation.

Data: The best demonstration of the independence of chemical action and pump operation occurs when a pump is repaired or replaced. Whenever a pump is removed for repairs, it is common practice to add chlorine, balance the pH, and remove the pump. Although the bottom of the pool gets dirty, water quality remains satisfactory during this interval (which may be as long as a week) as long as the water chemistry is kept balanced. Chemical mixing while the pump is inoperative takes place in accordance with the law of random thermal motion of submicron particles.

BELIEF #10. "LARGER PUMPS IMPROVE POOL CIRCULATION."

Observation: Larger pumps increase pool circulation rates, but the increase in circulation rate is accompanied by an even larger increase in energy consumption. As a result, larger pumps result in. less efficient circulation unless they are matched to proper hydraulic designs.

Data: Efficient pumping operation involves circulation of a maximum amount of water with a minimum amount of pump horsepower. A system which will pump 60 gallons per minute per kW of electrical input power is more efficient than a system which will pump 40 gallons per minute of electrical input power.

The energy delivered by a pump is dependent on the product of the pressure developed and the flow developed. For a given hydraulic system, the relationship between pressure and flow is non-linear.Pressure increases faster than flow. Hence, doubling the HP of a pump will more than double the pressure developed, but will not double the flow. Typically, to double the flow, it is necessary to use 6 times as much electrical power if no hydraulic changes are made.

A better way to double the flow in a new pool design is to cut the hydraulic resistance in half and use the same size pump. The marginal cost of doubling circulation system efficiency is usually less than $100.

Chapter 4 (see full version)

Chapter 5 (see full version)

5.5 GENERAL RECOMMENDATIONS FOR RETROFIT AND REPAIR WORK

It is difficult to make specific recommendations regarding the best choices of retrofit options for any particular pool. The reason for listing specific measures taken in the preceding discussion was to provide a partial set of guidelines to be used by the pool professional when considering recommendations to customers. However, a number of general recommendations can bemade which apply to most pools.

1. When replacing a pump, use a 0.75 HP or smaller pump when pipe size is 1.5-inch .

Larger HP pumps do not provide sufficient additional flow to justify the additional power consumption. High head (pressure) pumps will usually be needed when cleaning *systems* are present and will usually perform better than medium head pumps when 1.5 inch pipe is used.

2. When replacing a pump or filter, eliminate as many sharp 90-degree elbows as possible by replacing them with sweep 90-degree elbows, 45-degree elbows or flexible pipe.

Each 90-degree elbow is equal to 5 to 10 feet of straight pipe. Sweep 90-degree and 45-degree fittings cut losses due to change-of-direction nearly in half. In addition, they help to minimize turbulent flow which can increase the noise of the pumping system.

3. When replacing a filter, replace it with a filter rated at a minimum of 50 per cent more than the design flow rate.

Larger filters provide less hydraulic resistance to the system and require cleaning less often. There is reason to believe that larger filters should last longer since the filter elements in cartridge and diatomaceous earth filters are subjected to less pressure across them; i.e., the flow is distributed across a larger area.

If a sand filter is used, it is important to be sure that a flow of 15 GPM per sq ft of filter area is possible for backwashing. If the filter is chosen to have 13 GPM per sq ft for normal circulation, the required backwashing flow rate should be obtained, since during backwashing the restriction of the return piping is eliminated. However, if the filter backwash is piped away from the filter for a relatively long distance or through pipe which is too small, the backwash flow might be inhibited.

For diatomaceous earth filters, it may be necessary to disassemble the filter for manual cleaning if backwashing flow is less than 1.0 GPM per sq ft. However, since the cleaning interval is extended significantly with the use of a larger filter, manual cleaning is not considered to be a major problem. In fact, less water is used in the cleaning process if it is done manually.

4. When replacing a time clock, consider the use of a clock which will allow a minimum running interval of 15 minutes ~~or~~ less whenever the pool is unscreened or surrounded by heavy vegetation.

Pools that are equipped with types of automatic cleaning equipment that rely on filtration through the main drain will not gain benefit from the use of short settings for frequent skimming action; they therefore can be matched with any type of time clock.

5. It should be emphasized to owners of time clocks having an on-off- auto switch that if the switch is left in the on position (override), the pump will stay on until the switch is manually shut off again.

It is very important to remember to turn off the switch; otherwise the pump could end up running for hours, days or even weeks. Manufacturers considering entering the market with short interval timers are encouraged to develop a means of shutting the pump off automatically after a certain time, similar to the way the "off" tripper turns the pump off after a manual override on clocks presently in common use.

6. Observe carefully water circulation patterns in a pool. Improperly adjusted eyeballs can cause a multitude of circulation problems.

Too much ripple resulting from eyeballs aimed upward can cause debris to sink before it is skimmed off the surface. Too much surface water motion parallel to the side of the pool in front of a skimmer can wash debris past the skimmer before it has a chance to be drawn into the skimmer. On the other hand, properly aimed eyeballs can enhance the action of the main drain as well as the skimmer. Often an eyeball at the deep end aimed toward the main drain will stir up bottom debris enough to get it caught in a flow pattern either to the main drain or to the skimmer. Proper adjustment of eyeballs requires patience, imagination and skill.

7. When major modifications are considered for ~n existing pool, the new pool general sizing guidelines of Table 6.1 may be used to provide assurance of efficient operation.

If automatic cleaners or if heaters are present, a more detailed hydraulic analysis should be made to assure that sufficient pressure will be available for operating the auxiliary equipment in its intended manner.

8. It appears that incentive programs to encourage replacement of circulating pumps with smaller HP replacements might be a promising way to further reduce kWd and kWh.

The cost of operation figures shown in Table 5.3 can serve as a general guideline for the determination of kWh savings achievable through such a program. It also indicates the additional kWh which might be expected if the trend toward larger HP pumps continues.

6.4 RECOMMENDATIONS

Since effective filtration of swimming pool water depends on maximizing flow rate for any given pump size and since maximizing flow rates depends on the reduction of unnecessary head loss, it is recommended that the design and construction of pools be carried out in a manner which will lead to reduction of head loss. To facilitate low head loss design, the following recommendations are made:

1. Keep piping head loss below 5 feet of head per 100 feet of pipe.

This is equivalent to limiting the flow rate in 1.5-inch schedule 40 PVC to 25 GPM. Maximum flow rates for 2-inch schedule 40 PVC would thus be 50 GPM, and for 2.5-inch schedule 40 PVC, 80 GPM. It is important to be able to achieve a velocity of 5 feet per second in suction piping for the purpose of sand removal from the line. When separate main drain and skimmer lines are used, it may be necessary to shut off one occasionally in order to achieve velocity sufficient for cleaning the other.

2. Since sharp 90-degree ells are the equivalent of -5 to 10 feet of straight piping, their use should be avoided.

Whenever possible, 90-degree ells should be replaced with 45degree ells, sweep ells, or flexible piping. In addition to reducing head loss, elimination of 90-degree ells from the hydraulic system can help minimize turbulent flow through piping. Turbulent flow leads to added vibration and can cause resonance effects which lead to noisy pump operation. If pumps are to be run at night, it is important to keep noise at a minimum. Since some utilities are now offering lower rates for nighttime electrical use, it is likely that nighttime pump operation will increase.

3. Head loss through filters can be reduced by using larger filters.

For high rate sand filters, reduction of the recommended maximum flow rate from 20 GPM per sq ft to 13 GPM per sq ft is recommended. For diatomaceous earth filters, reduction of the maximum recommended flow rate from 2 GPM per sq ft to 1.3 GPM per sq ft is recommended. For cartridge filters, a maximum flow rate of 0.50 GPM per sq ft is recommended. These recommendations are equivalent to recommending that filters be oversized by 50 per cent in accordance with present rating standards.

The side benefits of changing filter ratings (or oversizing filters) include less frequent cleaning, better filtering, and longer filter life. The first benefit is obvious. .Better filtering and longer filter life should result from less pressure being applied across the filter membrane. Moreover, it is easier to backwash sand filters operating at low flow rates, since the filtered materials do not penetrate as deeply into the filter medium.

Sand filter maximum size is limited by backwashing requirements. The pumping arrangement must be able to deliver 15 GPM per sq ft of filter for effective backwashing. Since the backwash flow rate exceeds the normal circulation flow rate, the suggested 13 GPM per sq ft establishes a maximum filter size as well as a recommended minimum filter size.

If the design flow rate for a system with a diatomaceous earth filter is less than 1.0 GPM per sq ft, it may not backwash thoroughly. The filter cleaning problem can usually be solved by opening the filter and manually washing the filter elements.

4. Pump manufacturers and filter manufacturers can do a favor for pool contractors by manufacturing equipment with fitting sizes consistent with the flow rates and pipe sizes of recommendation .#1.

For example, a 15 sq ft diatomaceous earth filter would have 1.5-inch fittings and internal piping, but a 25 sq ft unit would have 2-inch. fittings and internal piping and a 48 sq ft unit would have 2.5-inch fittings and internal piping. Pump fittings of at least 2-inches on both suction and discharge are recommended for pumps up to 1 HP. For larger pumps, larger fittings are recommended.

5. Eyeball sizing, location, and number are important criteria in friction loss calculations.

Since hole size relates to velocity, which affects the cleaning power of the inlet, consideration should be given both to each individual inlet and to the combined open area of all of the inlets in determining their friction losses. Charts are available which present head loss vs. flow rate for the standard hole sizes.

6. It is recommended that the content of design manuals be reviewed along with NSPI design guidelines and that a consistent set of energy efficient design, maintenance, and operating guide lines be promulgated by the industry. These guidelines should be cost effective with respect to first cost as well as with respect to operating cost.

Numerous well-written design manuals are available to the pool professional (see bibliography). Most of these manuals do an excellent job of explaining how to match pump curves to pipe curves, and some of these manuals discuss the economic trade-offs between higher construction cost and lower operating cost. Existing pools indicate, however, that not a great deal of attention is paid to the content of these manuals.

7. It would be useful if pump manufacturers would rate pumps according to input electrical power (kW) in addition to the HP rating.

Rating pumps according to input kW would help to eliminate the confusion over up-rated and full-rated pumps and the corresponding power consumption of the motors. The power consumed by a pump motor is determined by the hydraulic load on the motor, which in turn is largely determined by the design of the pump housing and impeller. A motor can deliver hydraulic output which exceeds its nameplate HP rating, and high service factor motors of a given HP rating can deliver more HP than low service factor motors of the same rating. The service factor of a motor is equal to the ratio of the maximum allowable continuous HP consumption of the motor to the nameplate rated motor HP. Full rated pumps have high service factors and up-rated pumps have low service factors.

It is not unusual for a 0.33 HP full-rated pump to consume more power than a 0.5 HP up-rated pump. In other words, a full rated pump may use more power than a larger up-rated pump. The ambiguity over pump ratings could be eliminated by the adoption of a simple kW rating system.

Chapter 7 (see full version)